MHD Physics in Stellar Environments

Rachel A. Osten, chair
U Md./GSFC

- Marc Audard, U. Geneva
- Tom Ayres, U. of Colorado
- Alex Brown, U. of Colorado
- Jeff Linsky, U. of Colorado
- Dave Huenemoerder, MIT
- Paola Testa, MIT
- Masahiro Tsujimoto, PSU
- Steve Drake, GSFC
- Mike Corcoran, GSFC
- Maurice Leutenegger, GSFC
- Jeremy Drake, CfA
- Brad Wargelin, CfA
- Lidia Oskinova, Potsdam
- Marc Gagne, West Chester U.
- Joe Cassinelli, Wisconsin
- Wayne Waldron, Eureka
- Rachel Osten, UMd/GSFC

Main Themes

- Dynamics of MHD Plasmas
- Mass Loss across the HR Diagram
- X-ray Stellar Population Studies

Motivating Science Questions

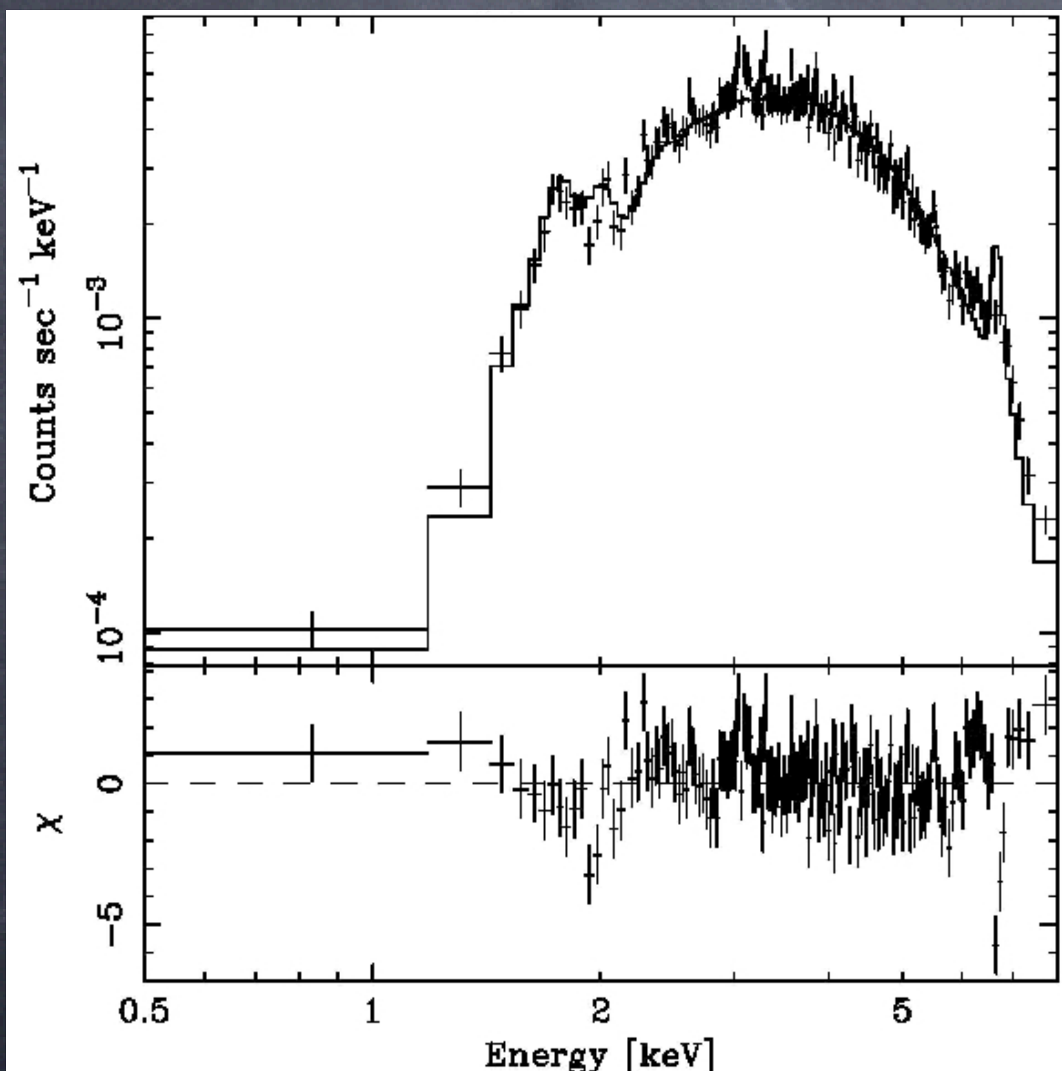
1. How typical is the physics of the solar corona in the context of stars?

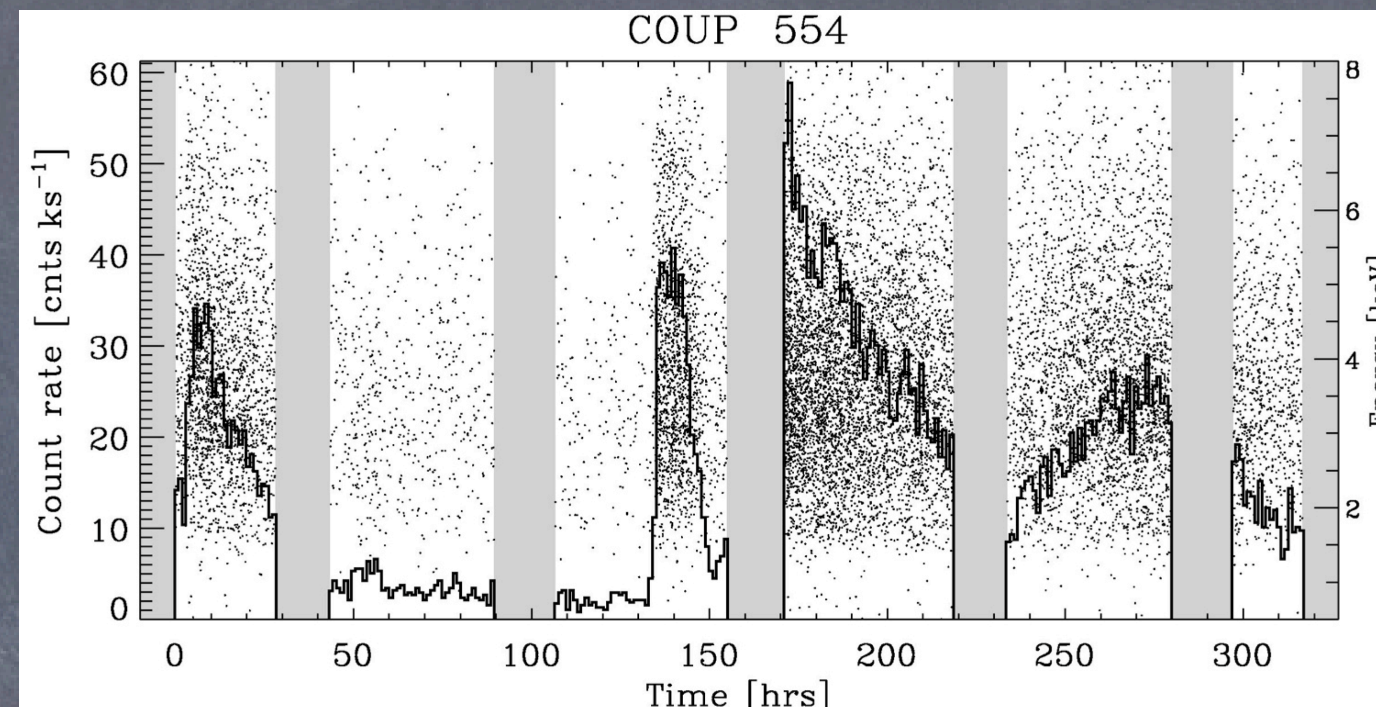
The nonlinear physics in MHD plasmas leads to complex temporal variations, whose dynamic X-ray emissions have been difficult to study. The Sun is one very well-studied star, but only one of billions.

2. How fast do stars lose mass, and what is the influence of environment on stellar mass loss/gain?

Mass loss is one of the fundamental astrophysical quantities which describes how stars interact with their environment, yet currently even in the best cases our inadequacies are being revealed.

averaging in time and wavelength glosses over important physics





embedded young star (L_X 10^{31} at 450 pc) seen in COUP data; dynamics obvious from light curve but spectra average over variability

despite the wide variety of different stellar environments in which flaring is seen, similar phenomena imply apparently very similar physics

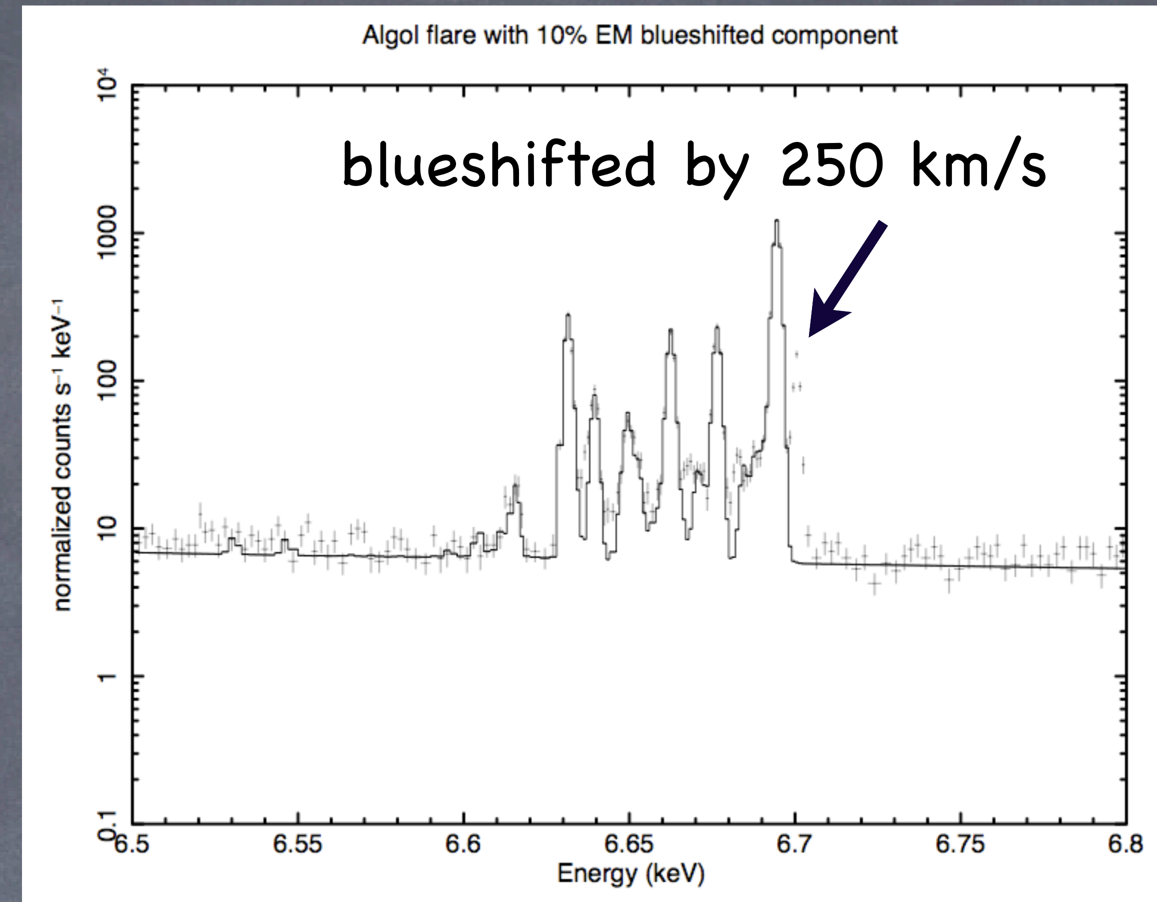
- temperatures, abundance anomalies in hyperactive close binaries, dMe flare stars, hyperactive young stars
- apply simple solar flare loop models to flares on active binaries, dMe flare stars, young stars, brown dwarfs, single active evolved stars -> same physics or garden path?

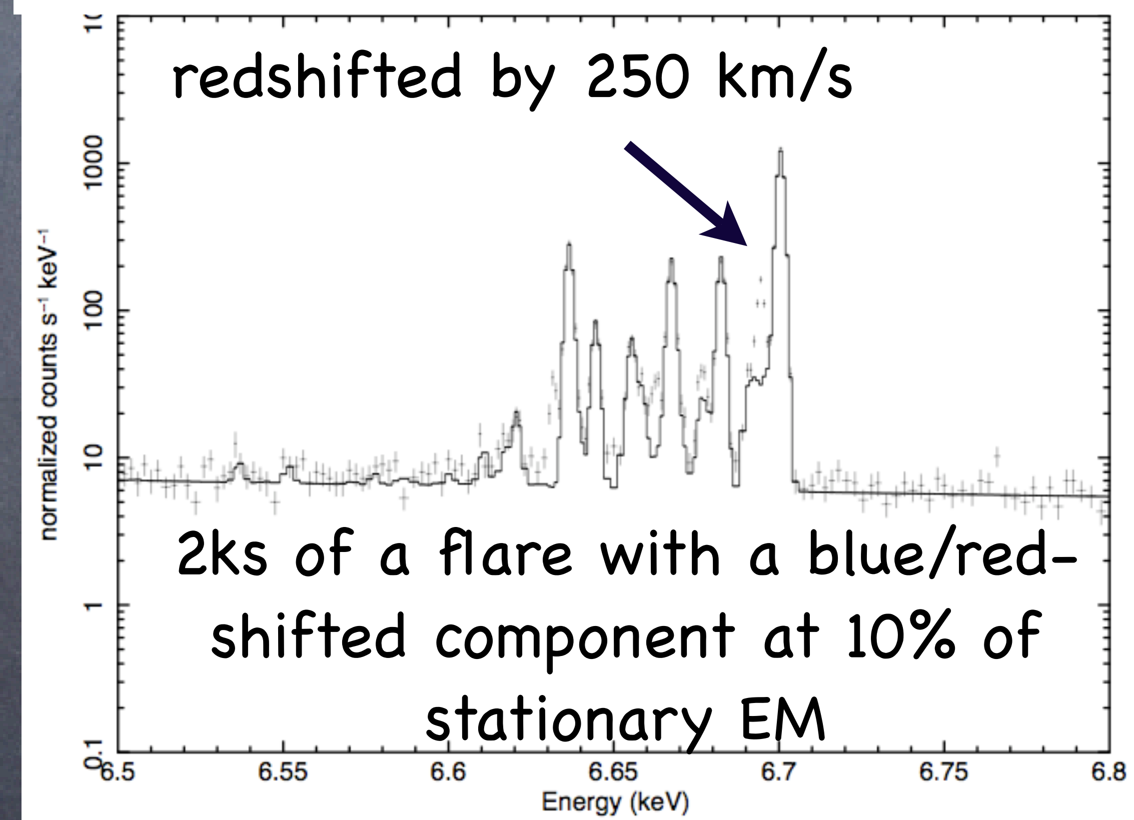
Dynamics of Reconnecting Plasmas

flare timescales <10s (impulsive phase)–1000s (decay phase)
expect mass motions, Kα fluorescence, time-varying abundances, densities, temperatures

~60 stars w/previous evidence for

flares f_x >1e-11, binning of 1-2 ks (smaller for larger flares)
flare duty cycle up to 30% for large flares, exposures 10s of ks

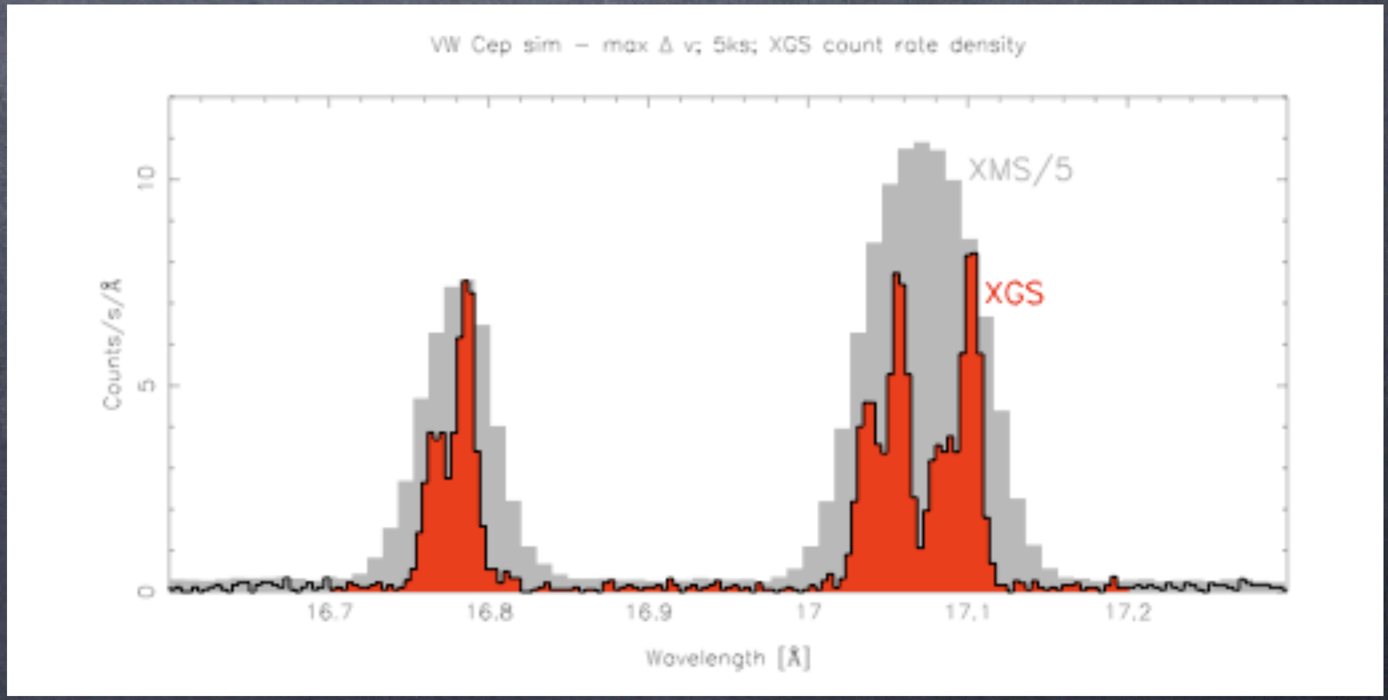




The Faces of a Star

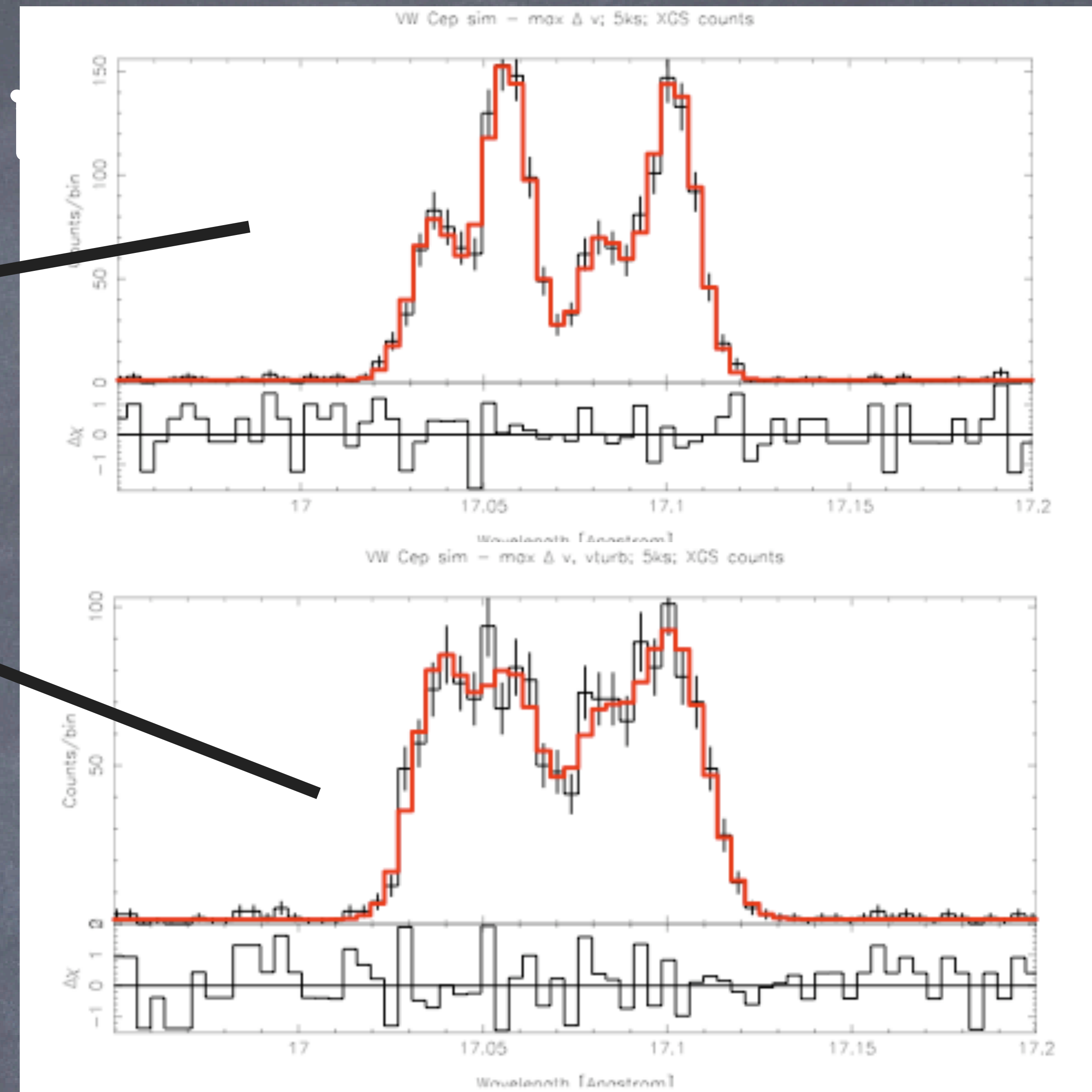
- extent & location of coronal structures
- based on VW Cep, 0.25d contact binary, fx~1e-11 at max Δv=350 km/s

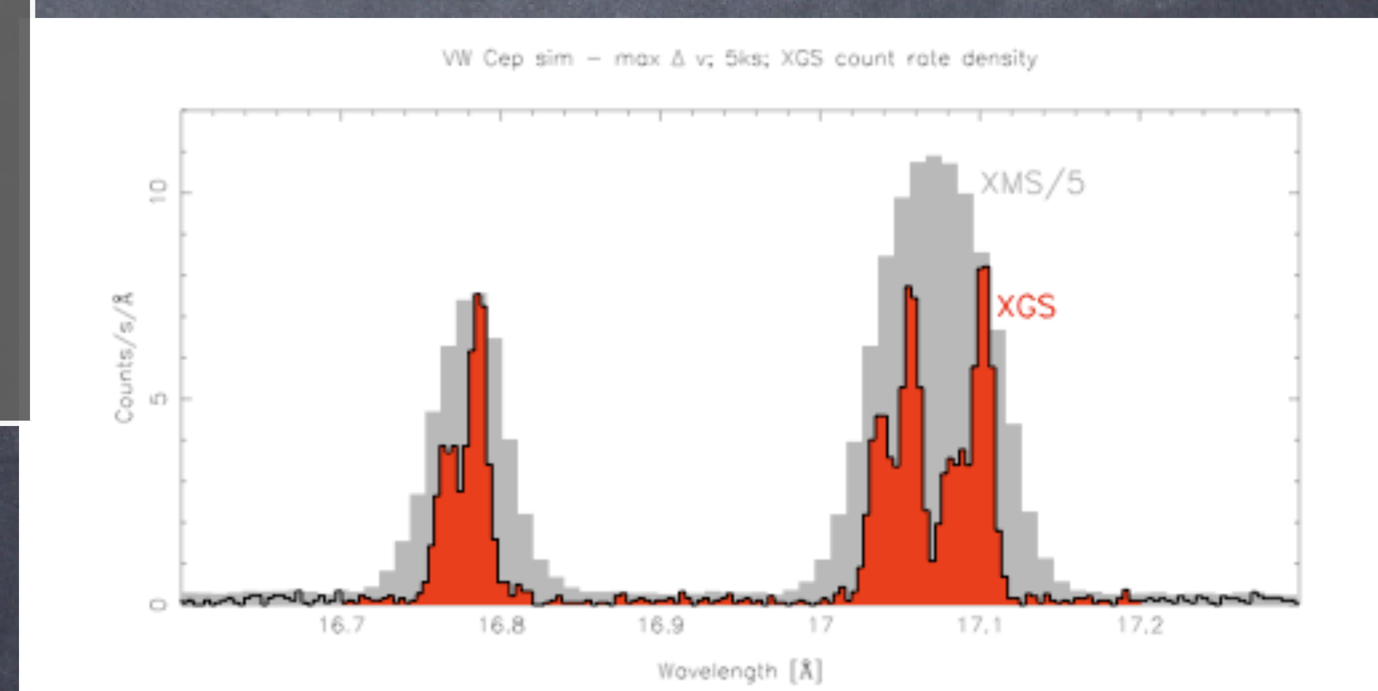
reconstruction of VW Cep x-ray emitting regions (white patches) based on composite line profile analysis and light curves from HETG spectra (see Huenemoerder et al 2006ApJ...650.1119H)



The Faces of a Sta

	thermal broadening	+rotational broadening
velocity	10-20 km/s	40 km/s
line flux	10%	20%
line width	upper limit 54 km/s	67 (34-105) 122 (90-143)

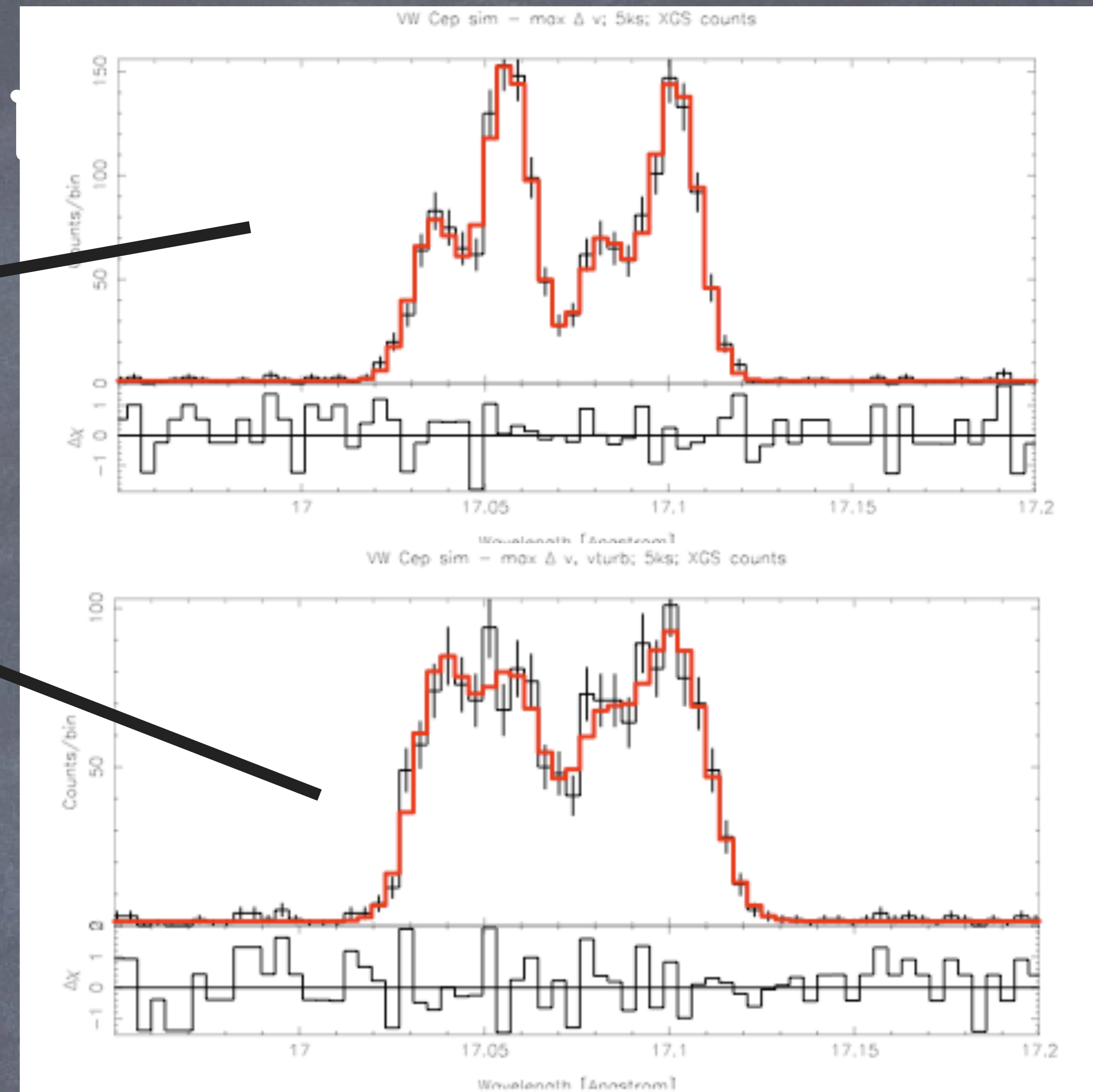


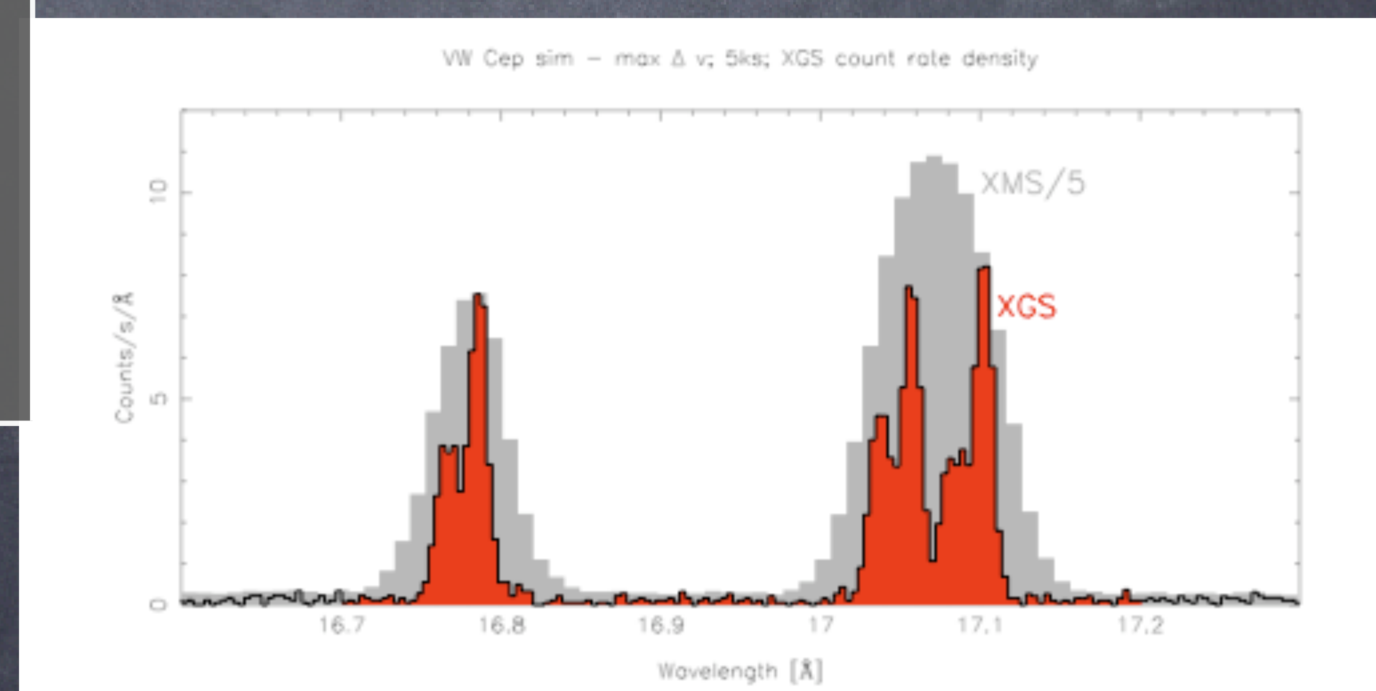


The Faces of a Sta

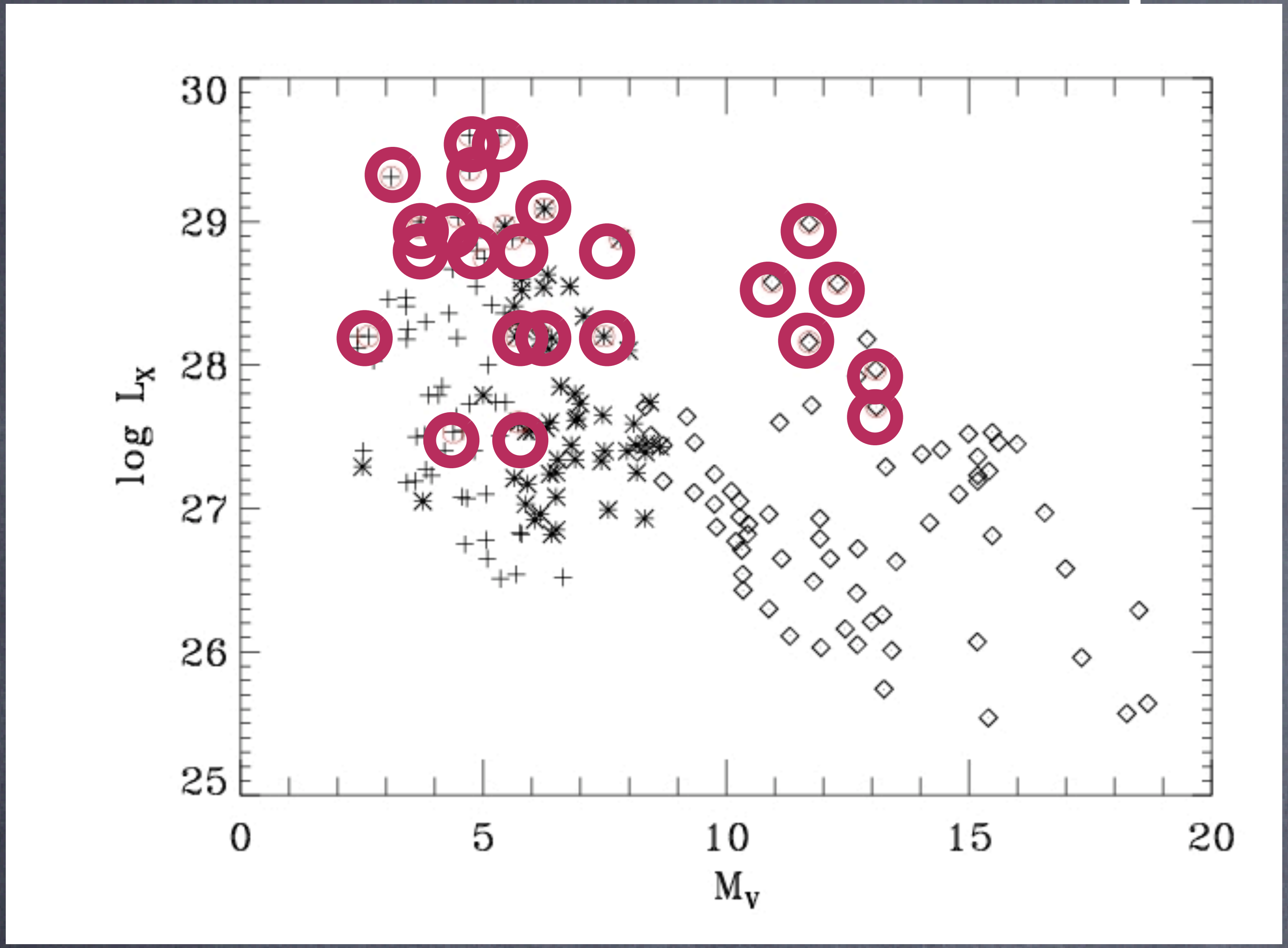
	thermal broadening	+rotational broadening
velocity	10-20 km/s	40 km/s
line flux	10%	20%
line width	upper limit 54 km/s	67 (34-105) 122 (90-143)

Doppler mapping of coronal structures: ~22 detached binaries with $F_x > 10^{-12}$, $P_{orb} < 2$ days



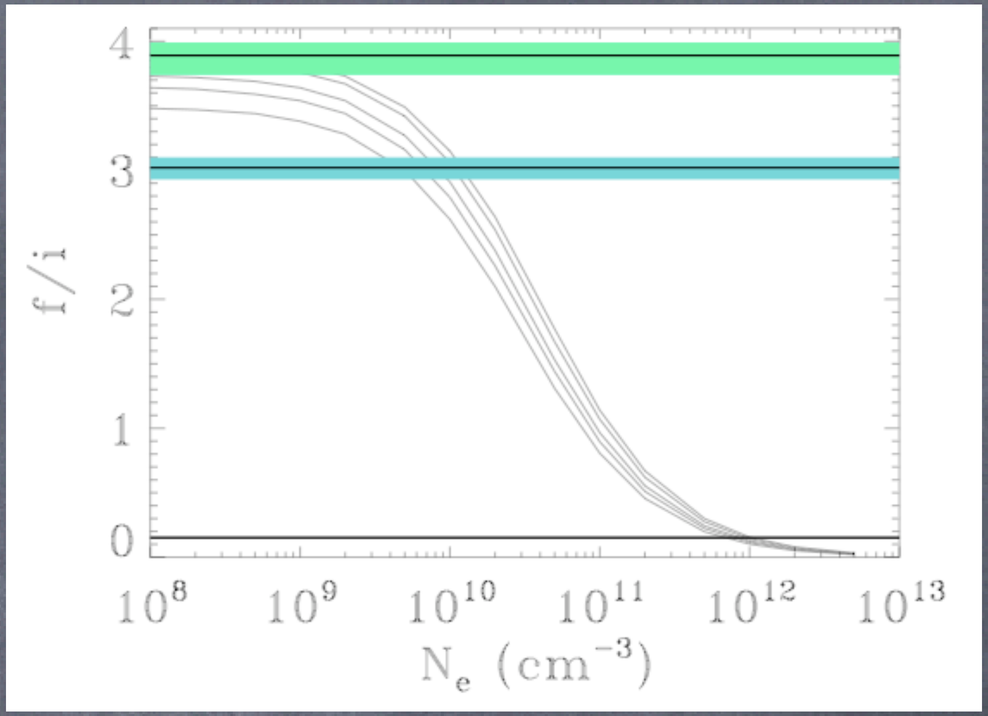


Beyond the Nearest & Brightest: X-ray Stellar Population Studies



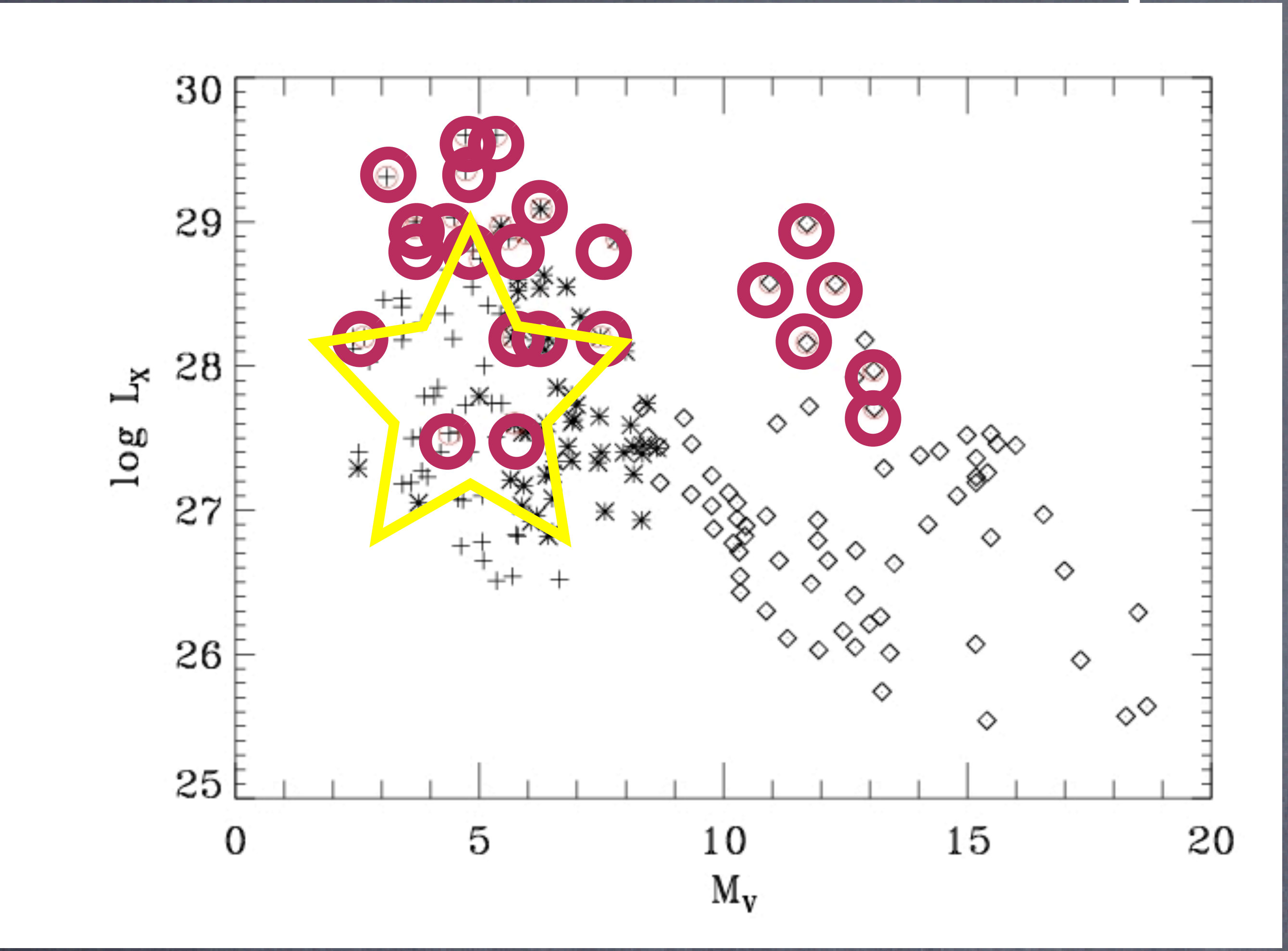
Schmitt & Liefke 2004 ROSAT nearby FGKM stars out to 14 pc

O VII line ratio

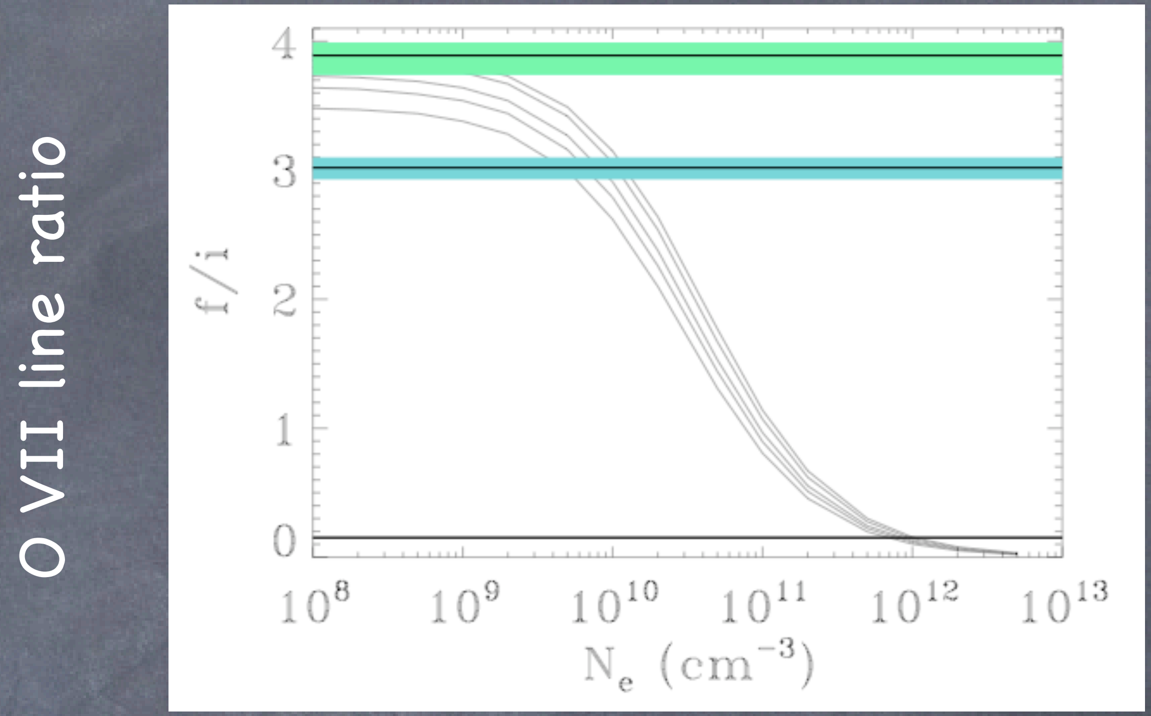


- 1ks XMS obs'n to get density constraint on moderately active K dwarf
- 26 stars with T_{exp} < 4ks per star for similar constraints; do survey of O-emitting coronal plasmas in moderately active K dwarfs in 100 ks

Beyond the Nearest & Brightest: X-ray Stellar Population Studies

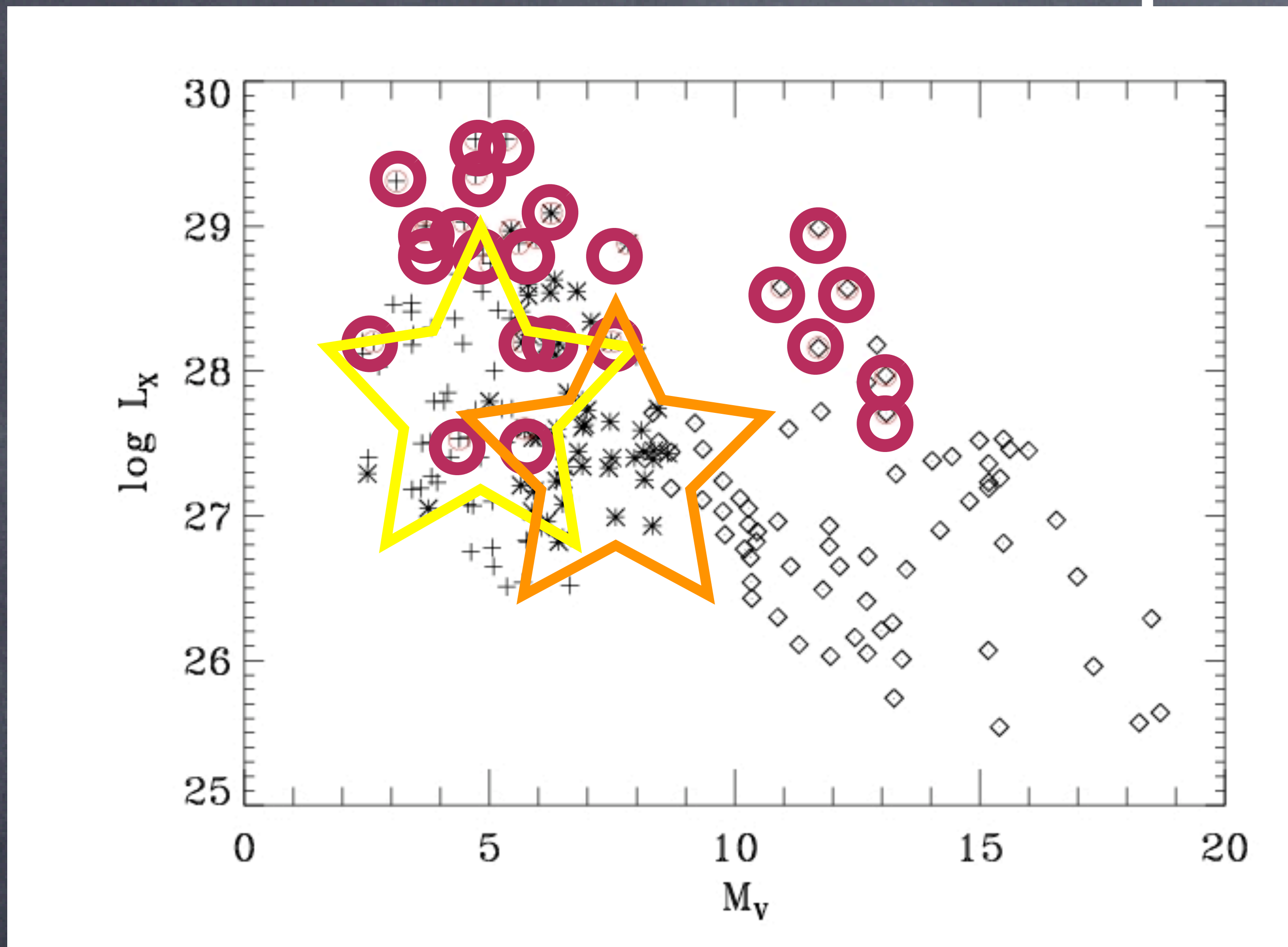


Schmitt & Liefke 2004 ROSAT nearby FGKM stars out to 14 pc



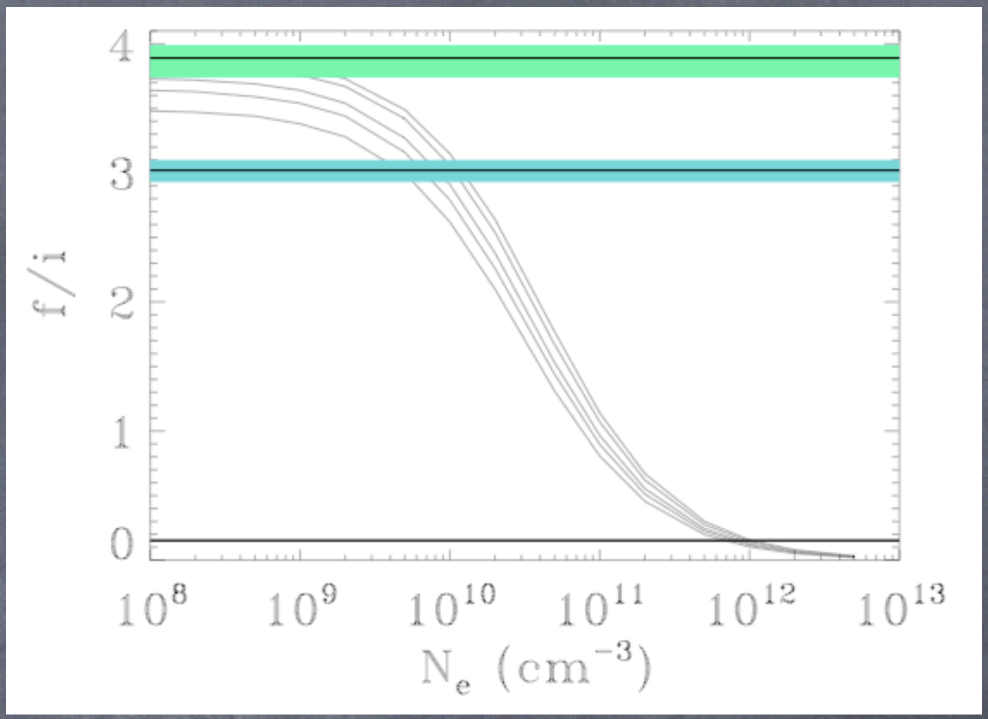
- 1ks XMS obs'n to get density constraint on moderately active K dwarf
- 26 stars with T_{exp} < 4ks per star for similar constraints; do survey of O-emitting coronal plasmas in moderately active K dwarfs in 100 ks

Beyond the Nearest & Brightest: X-ray Stellar Population Studies



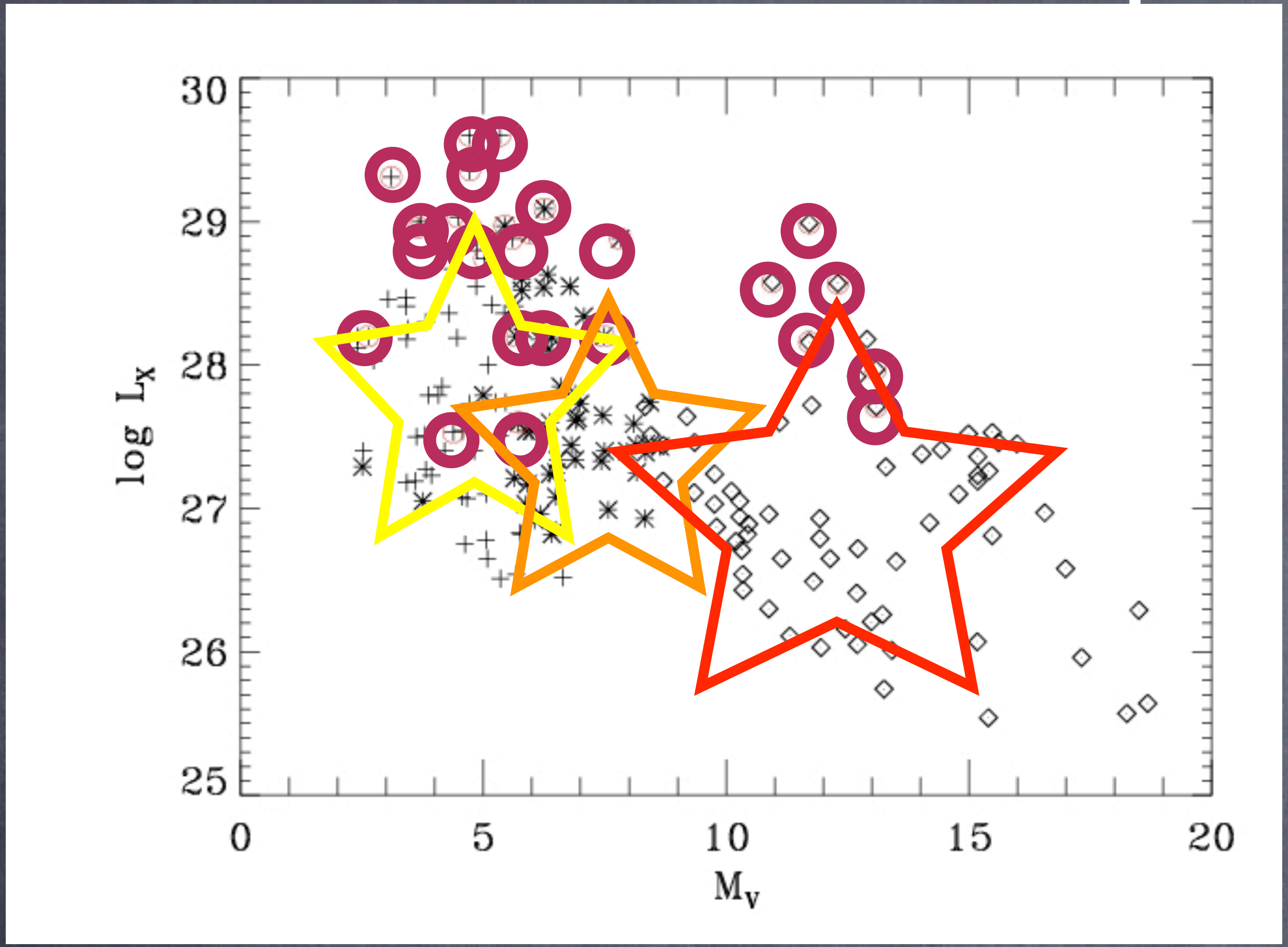
Schmitt & Liefke 2004 ROSAT nearby FGKM stars out to 14 pc

O VII line ratio



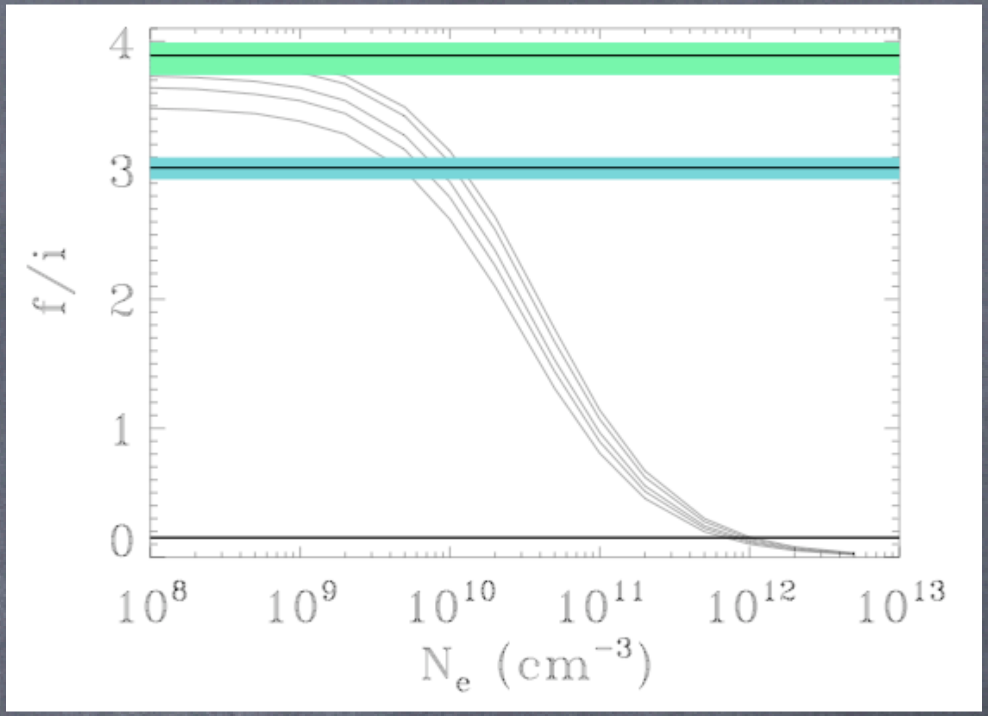
- 1ks XMS obs'n to get density constraint on moderately active K dwarf
- 26 stars with T_{exp} < 4ks per star for similar constraints; do survey of O-emitting coronal plasmas in moderately active K dwarfs in 100 ks

Beyond the Nearest & Brightest: X-ray Stellar Population Studies



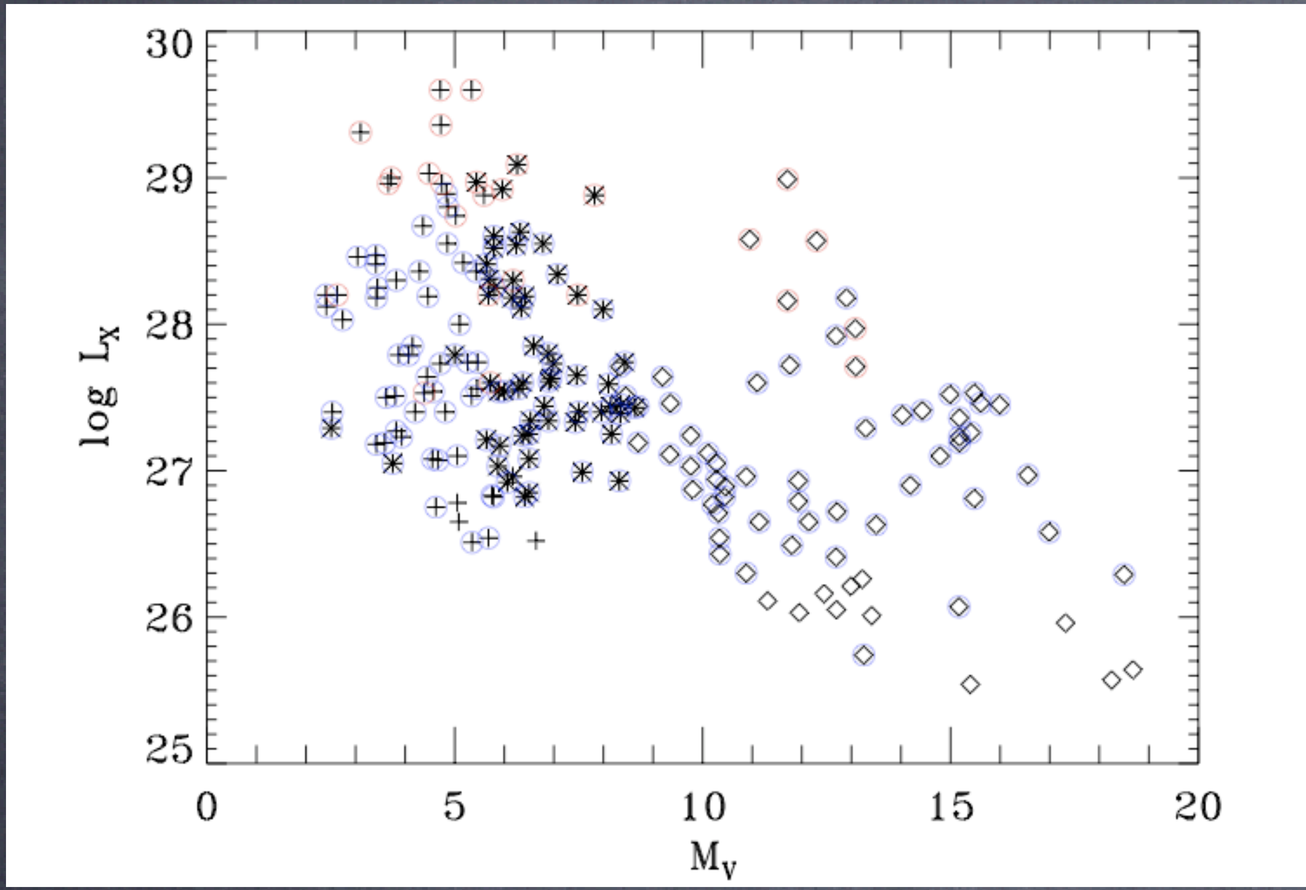
Schmitt & Liefke 2004 ROSAT nearby FGKM stars out to 14 pc

O VII line ratio

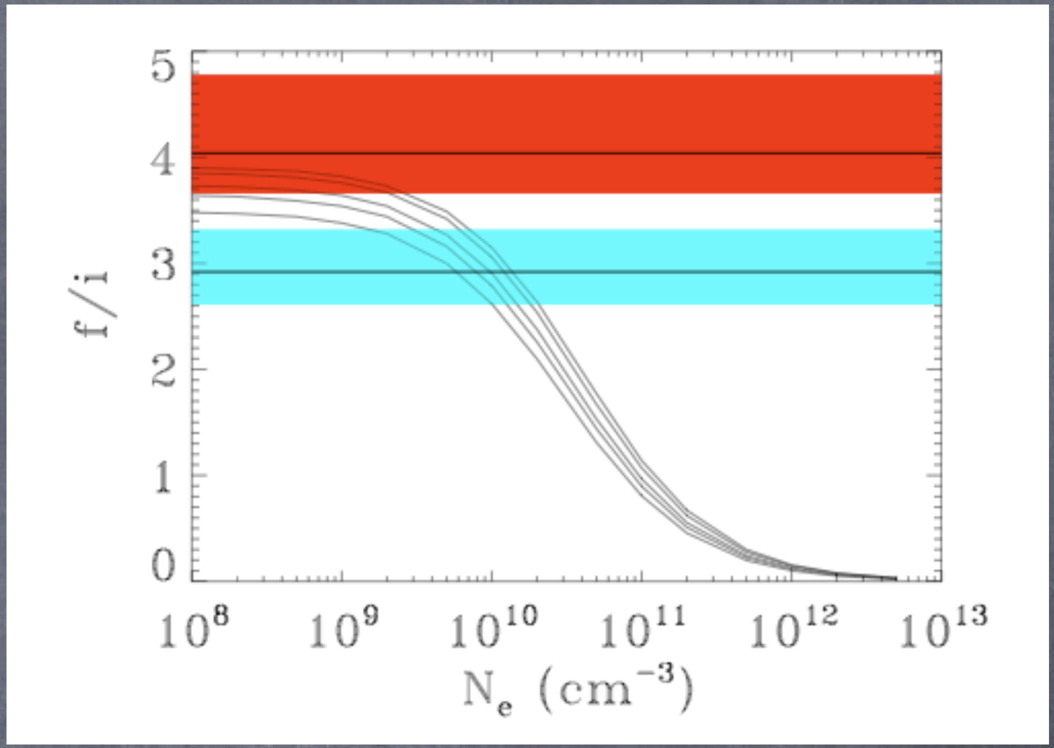


- 1ks XMS obs'n to get density constraint on moderately active K dwarf
- 26 stars with T_{exp} < 4ks per star for similar constraints; do survey of O-emitting coronal plasmas in moderately active K dwarfs in 100 ks

X-ray Stellar Population Studies



Schmitt & Liefke 2004 ROSAT nearby FGKM stars out to 14 pc

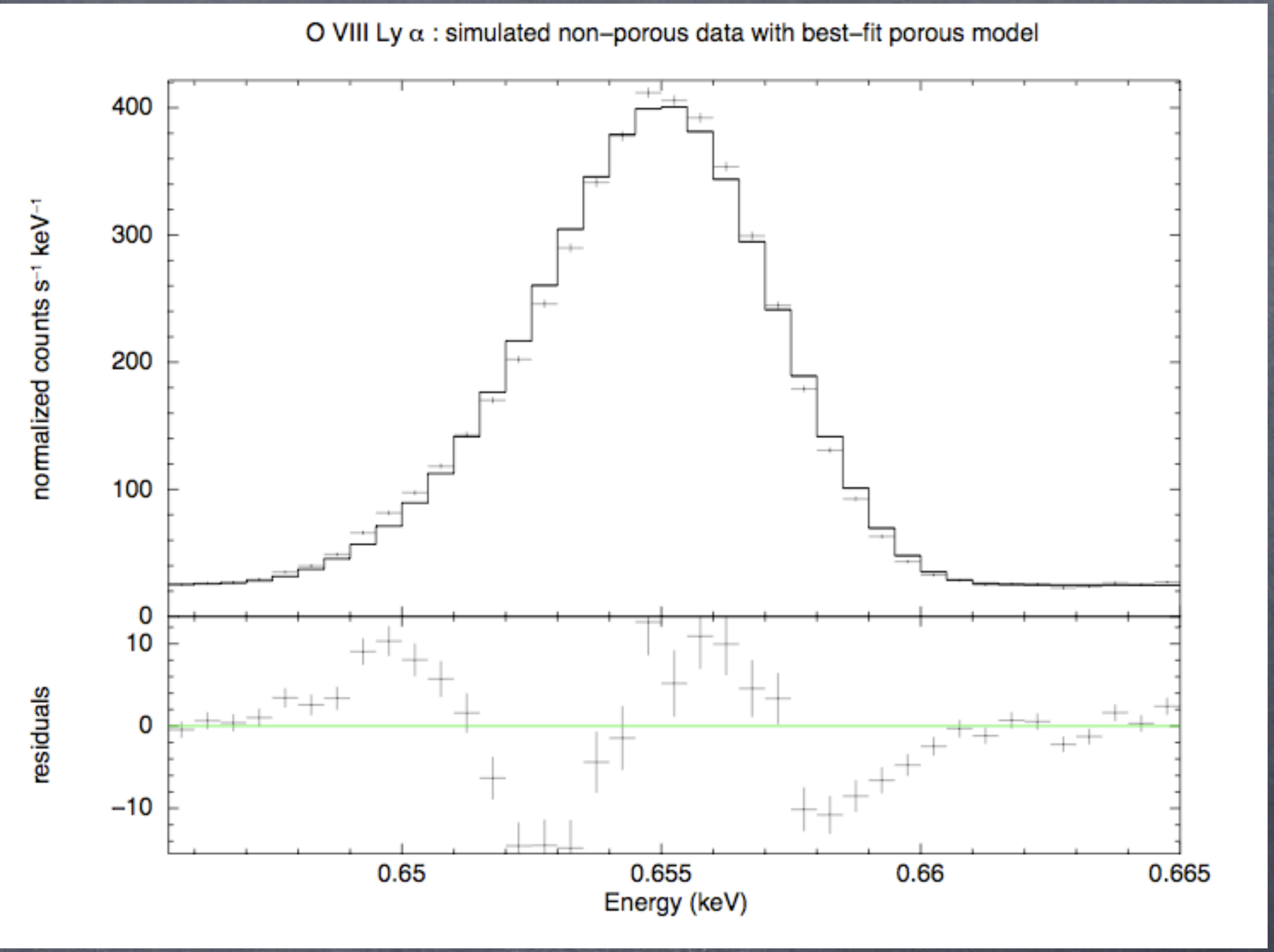


- 50ks XMS obs'n to get O VII density constraint on a "solar active region" star (L_X=2e26) at 5 pc
- ~173 stars with f_X>6.6e-14

  amenable to ≤50 ks observation

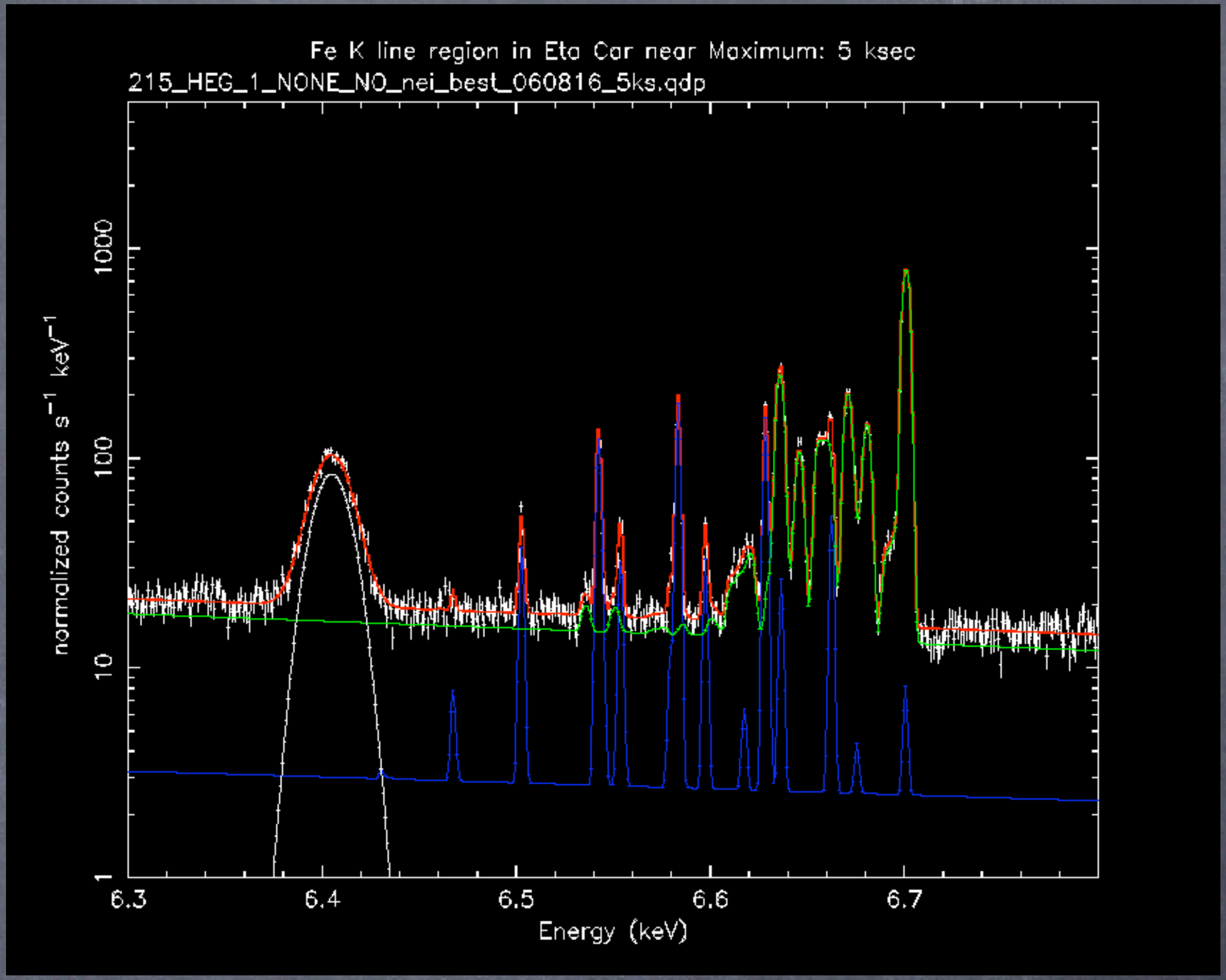
Mass Loss

- how smooth are the winds from OB stars? how has this affected previous mass loss rates?
- high SNR line profiles provide a discriminant between clumpy and nonporous winds
- t_{exp} of 50 ks: do same analysis as shown for 36 stars (based on RASS of bright OB stars), # that have strong winds likely smaller



porous model applied to non-porous smooth wind "data"; model has 5x higher mass loss rate

Dynamics of Stellar Winds



- colliding wind binaries: measure line centroids to 10 km/s: dynamical masses
- flow dynamics of hot shocked gas: orientation/direction/magnitude of flow velocity
- mass loss rates ind. of clumping in stellar wind
- ~2 doz. colliding wind binary

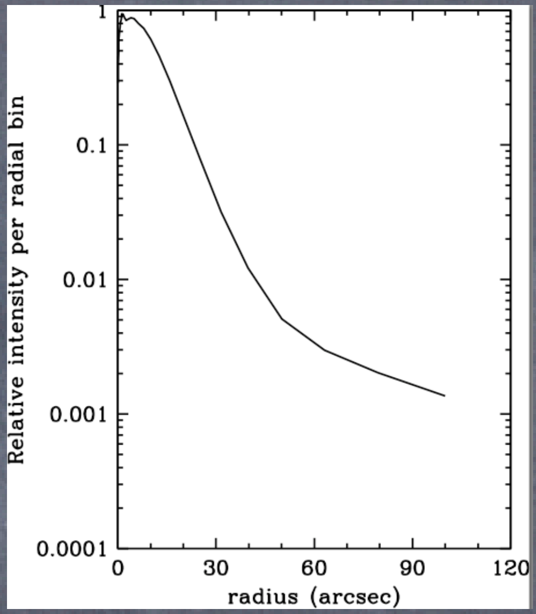
systems (OB+OB, WR+OB) exposures 5-10 ks

broad Fe fluorescence line
NEI line complex
Fe He-like triplet

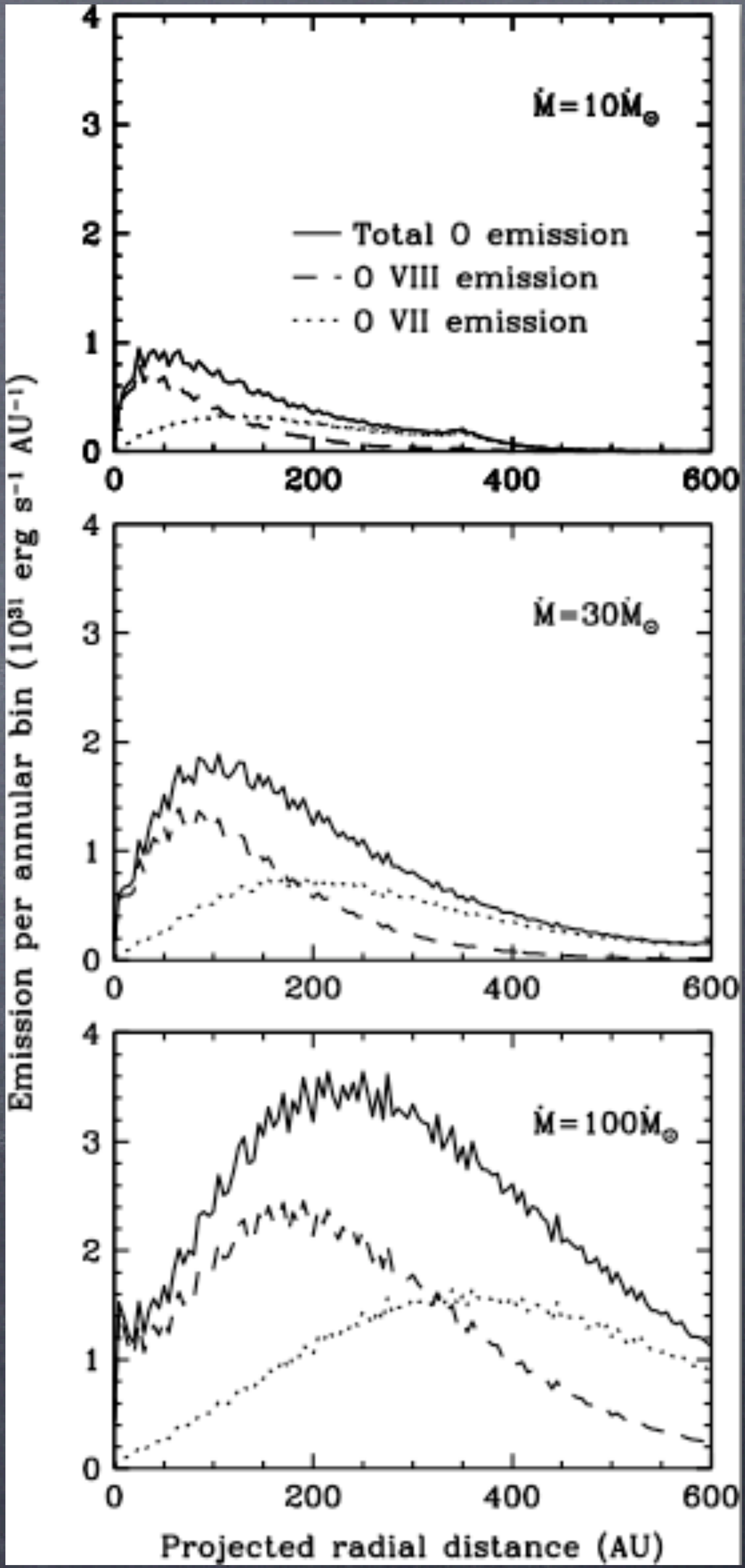
Mass Loss

- coronal emission dominates, but at 10^{-4} level, CX occurs in a halo around star as highly charged CO ions collide with astrospheric material
- need extended astrosphere, partially neutral ISM direction

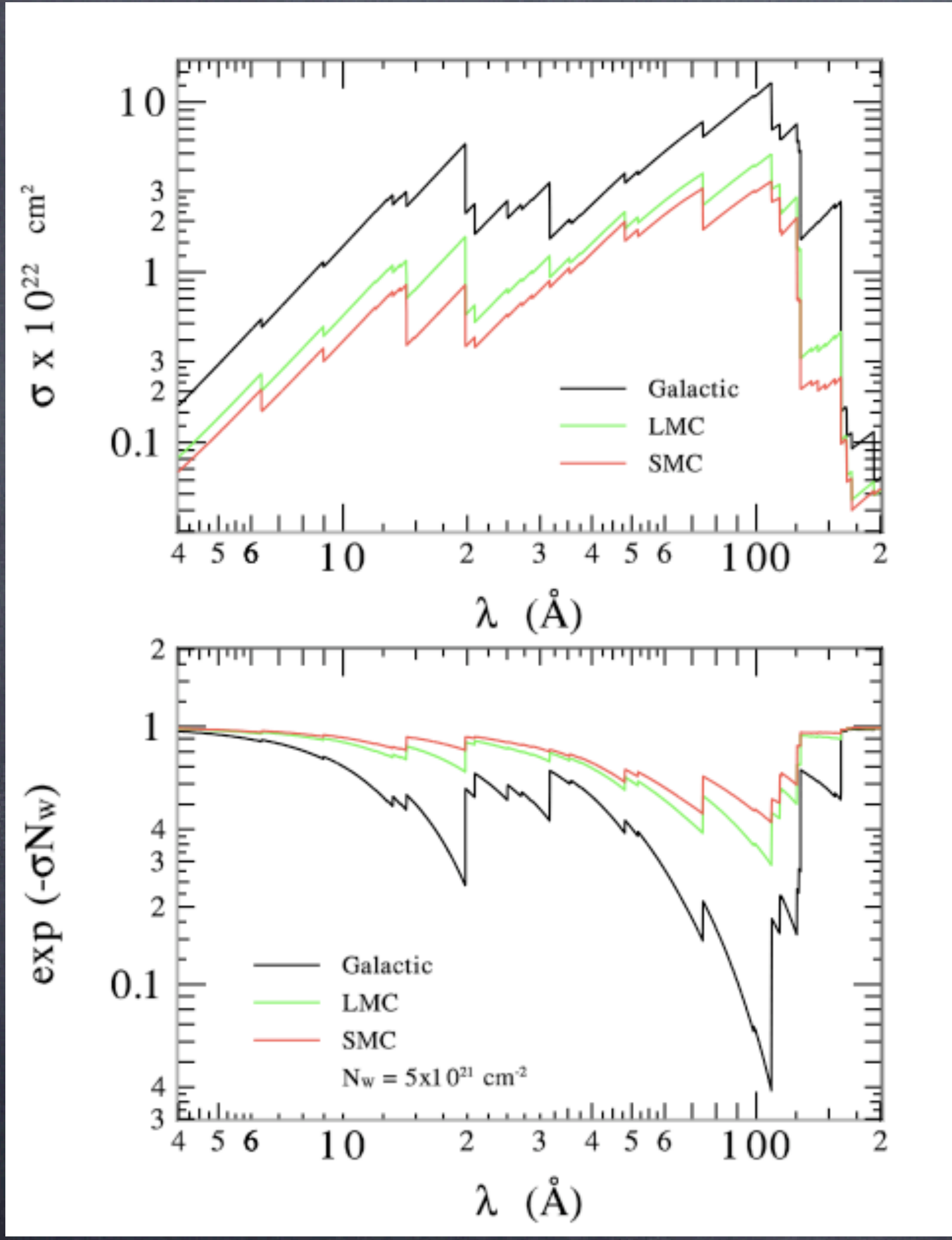
	d (pc)	$\dot{M}$ ($\dot{M}_o$)	Log L_x	astropause distance (AU)	annulus 50% CX flux (")	CX counts 100 ks
α Cen	1.35	2	27.7	20-30	15-45	1300
ϵ Eri	3.22	30	28.3	800-1600	55-180	3600
70 Oph	5.09	100	28.5	1000-2000	70-200	5000
36 Oph	5.99	15	28.3	350-700	20-40	500



Con-X radial PSF



X-ray Stellar Population Studies

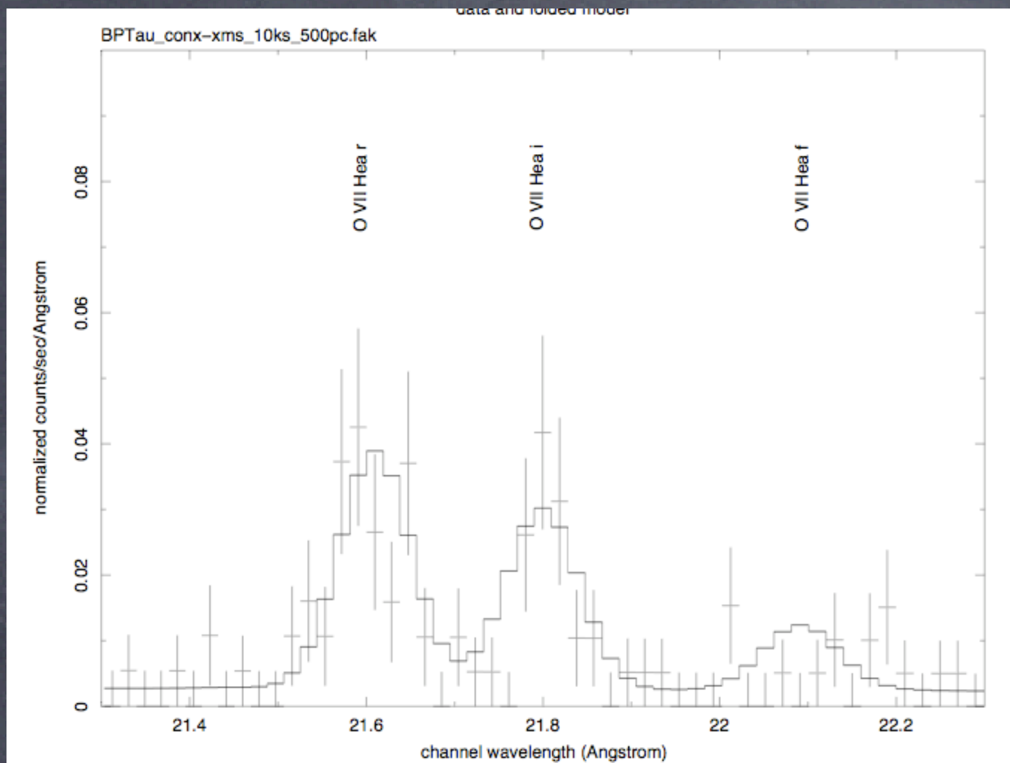


wind opacities for galactic, LMC, SMC O5 star

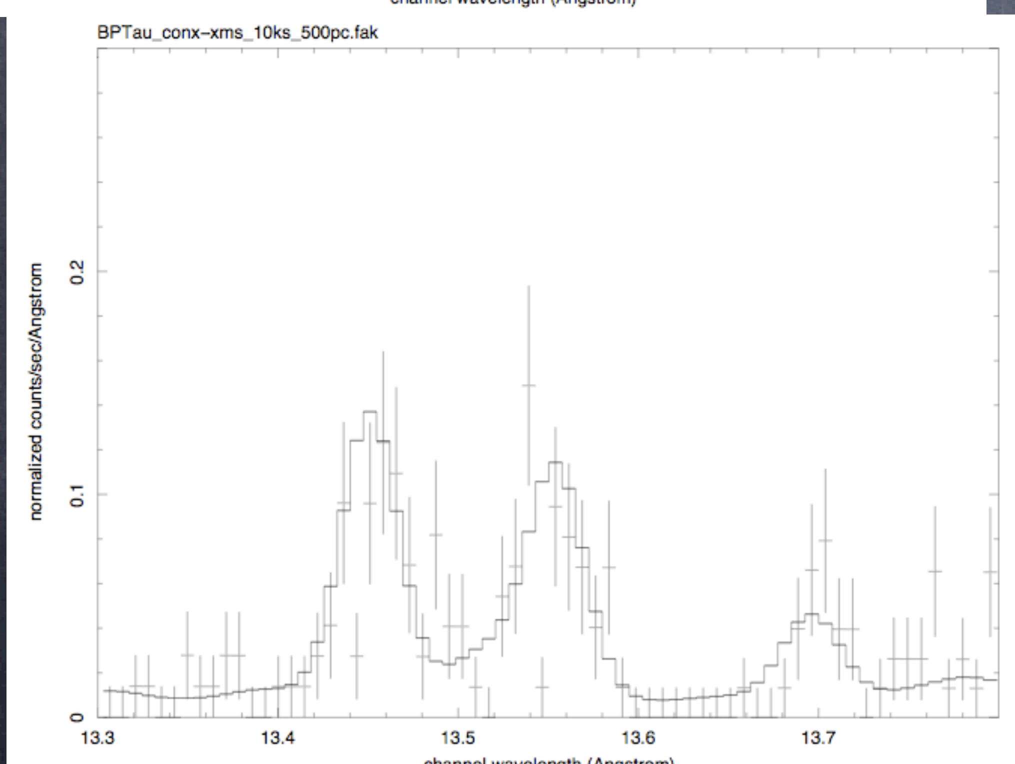
- stellar winds in different environments
- SMC, LMC lower opacity, smaller mass loss rates: intrinsically larger X-ray emission
- exposures 200-300 ks at 49, 58 kpc for similar quality as can be done now at 1.5 kpc, ~25 OB stars in SMC

connecting star formation with galaxy formation

X-ray Stellar Population Studies



10 ks Lx of 1e30 @500 pc



10ks Lx of 1e30@500pc

spatial confusion will be an issue for more distant clusters

- accretion in different environments
- O VII, Ne IX densities: Taurus distance 1ks snapshots, Orion distance 10 ks, further (1 kpc) in 50ks
- access embedded sources (Class I), N VI density in WTTS 10^9 cm^{-3}